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Full Name – IB Candidate # – Subject – Date

Descriptive Title of Experiment

Introduction:

- Provide relevant background information, which enhances the understanding of the context of this investigation.
- Give justification for choosing the topic under investigation, which demonstrates personal significance, interest, or curiosity.
- Show evidence of personal input and initiative in the designing, implementation, or presentation of the investigation, *throughout your report*.

Research Question:

- How does _____ (the Independent Variable) affect _____ (the Dependent Variable)?

OR…

What is the relationship between _____ (the Independent Variable) and _____ (the Dependent Variable)?

- Outline other factors that can affect the dependent variable. *Briefly outline them here, but fully describe how they will be controlled within the controlled variables section of the report.*

Hypothesis:

- Describe your hypothesis, or prediction, with scientific reasoning.
  A hypothesis is not required but it is prudent to include one so that you can refer back to it later in your conclusion and evaluation.

Independent Variable:

- How will this variable be changed in the experiment?
- How will this value be measured, or calculated from other measurements?
- Which measuring tool(s) will be used?
- What are the SI units of measurement?
- What is the error of uncertainty in the measuring tool(s)?
- If the independent variable is calculated, how is the uncertainty calculated?
- List a wide range of at least 8 - 10 changes to your independent variable, which are evenly spaced apart. Attach units to this list.

Dependent Variable:

- How will this value be measured, or calculated from other measurements?
- Which measuring tool(s) will be used?
- What are the SI units of measurement?
- What is the error of uncertainty in the measuring tool(s)?
- If the dependent variable is calculated, how is the uncertainty calculated?

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Controlled Variables:

- Identify ALL relevant controlled variables, beginning with the most significant.
- State the numerical quantity at which the controlled variable will be maintained, with SI units.
- Describe how this quantity is measured.
- Include the measuring tool(s) used.
- Include uncertainty in the measuring tool(s).
- If a controlled variable is calculated, how is the uncertainty calculated?
- Describe how the controlled variable might affect the measured dependent variable if it weren't controlled.
- *A table or bulleted list is a good way to organize this information.*

Materials:

- List all relevant materials to be used.
- Include numerical quantities and dimensions.

Labeled Diagram:

- Include a labeled diagram of your experimental setup, which includes dimensions.

Method:

- Write a clear step-by-step method, which appropriately addresses the research question.
- Explain how to set up the investigation.
- Explain how the data will be collected.
- Include a relatively wide range of at least 8 – 10 sets of data, which are evenly spaced apart.
- Describe how to address all of the significant factors that could influence the relevance, reliability, and sufficiency of the collected data.
- Explain how the data will be processed.
- Include a plan to repeat measurements (at least 5 trials), how to treat outliers, and how to take the average.
- Consider the significant safety, ethical, or environmental issues that are relevant to the investigation method.

Data Table(s):

- Organize data in a data table(s).
- For clarity, raw data and processed data should be in separate tables.
- Include a descriptive title to each table(s).
- Include a descriptive heading for each column: name, symbol, uncertainty, and SI units (Ex: Velocity, V, ± 0.1 ms^{-1}).
- Uncertainties are to one significant figure. Data numbers and uncertainties must show same decimal precision. (Ex: 3.10 ± 0.01 m).
- Include at least 8 – 10 sets of data, evenly spaced apart, and at least 5 trials of each measurement.
- Re-do trials that look like outliers.

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- Include averages of trials.
- Show all equations used, and one example of each calculation, including how to take the average.
- Include a description/justification for how to find the uncertainty(s).
- Uncertainties in trials, repeated measurements, should be calculated by (max value – min value)/2.
- All results of calculations must have SI units, uncertainties, and be rounded off appropriately. Uncertainties must be to one significant figure and the data must match the same decimal precision as the uncertainty.
- Include qualitative data.

Graph:

- Graph your averages/processed data on Excel, or a similar computer graphing software.
- The graph should be a **full page**, which includes a title, and labeled x and y-axes similar to the data table headings: name, symbol, uncertainty, and SI units (Ex: Velocity, V, ± 0.1 ms^{-1}).
- If possible, try to linearize the graph to fit the equation, y = mx + c, so that analysis is easier to discuss.
- Include error bars, a best-fit line, a *maximum gradient line, and a *minimum gradient line. Do NOT just connect the data points! You must use best and worst fit lines. **Gradient lines must intersect with all error bars**!

  For **Maximum Gradient**:
  - First (lowest) Data point:
  - x-coordinate: ADD the uncertainty to the first independent variable's value (*x*)
  - y-coordinate: SUBTRACT the uncertainty from the first dependent variable's value (*y*)
  - Last (highest) Data Point:
  - x-coordinate: SUBTRACT the uncertainty to the last independent variable's value (*x*)
  - y-coordinate: ADD the uncertainty to the last dependent variable's value (*y*)
  - **Estimate a maximum linear fit through those two new data points, *which still intersect through all other error bars*.**

  For **Minimum Gradient**:
  - First (lowest) Data point:
  - SUBTRACT the uncertainty to the first independent variable's value (*x*)
  - ADD the uncertainty from the first dependent variable's value (*y*)
  - Last (highest) Data Point:
  - ADD the uncertainty to the last independent variable's value (*x*)
  - SUBTRACT the uncertainty to the last dependent variable's value (*y*)
  - **Estimate a minimum linear fit through those two new data points, *which still intersect through all other error bars*.**
- Show gradient triangle, gradient calculation, and linear equation for each of the three lines. Determine the uncertainty in the best-fit gradient by (max gradient – min gradient)/2.
- Extend each line to intersect with the y-axis.
- Attach the graph to your lab report, between the data table(s) and the conclusion and evaluation.

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Conclusion:

- Include a description of the graph, describing a trend/pattern/relationship in the data.
- Write a conclusion based on the outcome of the investigation, which relates to a correct interpretation of the processed **data** and relates back to the original research question. *Refer to the validity of the original hypothesis, if you included one at the start.*
- Compare your experimental result/value with the accepted scientific context/value. Fully reference the accepted value. Include a citation, which links to a bibliography at the end of your report.
- Explain how the accepted value supports or contradicts your experimental result by explaining whether or not the accepted value lies within the range of uncertainty of your experimental result.
- A percentage error should be compared with the total estimated random error as derived from the propagation of uncertainties. (IB Physics IA Guide)
- Discuss weaknesses/limitations that could have affected the experimental results, which include issues with the method and consideration of random or systematic uncertainty.

Evaluation:

- Evaluate the quality of the data.
- Identify realistic sources, and types (random or systematic), of error/uncertainty in the experimental method.
- List sources of error/uncertainty in order of greatest to least significance.
- Comments about the precision and accuracy of the measurements are relevant here. (IB Physics IA Guide)
- When evaluating the procedure used, the student should specifically look at the processes, use of equipment and management of time. (IB Physics IA Guide)
- Explain how these sources of error/uncertainty could have affected the experimental results.
- Include quantitative (reference to the data) explanations as well as qualitative explanations.
- Suggest **realistic and specific** improvements to the method, to reduce or eliminate the identified error/uncertainty. Don't just say, "Use more precise equipment".
- Modifications to the experimental techniques and the data range can be addressed here. (IB Physics IA Guide)
- The modifications should address issues of precision, accuracy and reproducibility of the results. (IB Physics IA Guide)
- Suggest how to reduce random error, remove systematic error and/or obtain greater control of variables. (IB Physics IA Guide)
- ***A table, similar to the following, is a good way to organize this information:***

Order of Significance	Source of Uncertainty and How it Could Affect Outcome	Random/ Systematic	Possible Improvement to Reduce Uncertainty

- Include relevant suggestions for an extension to this investigation.

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Bibliography:

- Fully reference sources of information and accepted values in APA style format.
- Include APA style citations within the body of your report, which link to the bibliography.

Final check before submission:

- *Report is well structured, clear, and coherent.*
- *Report is relevant and concise, between 6 – 12 pages in length, with 12-point font.*
- *Subject-specific terminology and conventions are appropriate and correct.*
- *Use of third person throughout report as much as possible, with exception to the "Personal Engagement" criteria.*
- *Spelling, grammar, and symbols check.*